Abordagem Lean Six Sigma para atendimento de aumento de demanda de COVID-19. Estudo de caso em fabricante de respirador no Rio de Janeiro.

Lean six sigma approach for COVID-19 demand growth. A Case study in a Rio de Janeiro hospital respirator company.

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Article History:

Submitted: 2021 - 02 - 12 Revised: 2021 - 02 - 24 Accepted: 2021 - 02 - 25

Abstract: The current economic scenario shows a major recession caused by the crisis in public health due to the proliferation of the new corona virus. However, companies operating in the hospital segment have high demands and their products are widely used. However, old mistakes in operations management inhibited several production lines and achieving their manufacturing goals due to waste generated in the production processes. This article aims to increase the production capacity by 70% of the production line of surgical tubes in a hospital instrument industry located in the state of Rio de Janeiro. To achieve this objective, a lean six sigma project will be developed, conducted by the DMAIC methodology. From the 36-days analysis of the process, it was possible to reach the main low production problems and precisely find a way to increase production capacity in 55%, making possible to attend the new increasing demand from COVID-19 engaged hospitals. Also, due to directed actions, operators could increase their productivity ratio from 89 to145 products per hour by the end of May 2020.

Keywords: Lean Six Sigma; Lean Manufacturing; COVID-19; Demand forecast

1. Introduction

The current scenario of the global economy shows a recession caused by the public health crisis due to the pandemic generated by COVID-19 virus. Several organizations around the world are being impacted by social prevention measures to stem the spread of the virus (OPAS, 2020).

In this way, companies from different segments have reduced their ability to provide goods or services, since the entire supply chain and human resources were impacted by the containment measures and by the high rate of contamination. Countries as China and the USA, who holds the largest global market share were highly impacted (Abberger et al., 2020).

The pandemic triggered old production problems such as inventory excess, line imbalance, overproduction, low productivity machines and tools, high rework rates and short production stops that, when added up, generate large productivity losses (Nascimento, 2019).

When considering these triggers, the lack of supply, the reduction in products consumption that are not at the bottom of the human needs pyramid, companies are facing three different scenarios in this pandemic: (i) bankruptcy in the short / medium term; (ii) the search for survival in the market through disruptive innovation and (iii) the excessively increased demand for health-related equipment (Picchi, 2020).

In view of this scenario, the management approach employed by Lean Manufacturing associated with Six Sigma statistical methods is promoting lean solutions for different market segments. Together, Lean Six Sigma promotes process speed, eliminating waste, and reducing the variability of the main activities, through statistical control methods (Guimarães et al., 2020; Werkema, 2016; Barud et al, 2020).

This project aims to increase the production capacity by 70% of a production line of hospital respirator hoses by the end of the first half of 2020 of the hospital instrument industry located in the State of Rio de Janeiro through a Lean Six Sigma project.

2. Literature Review

2.1 Lean Manufacturing

Lean Manufacturing, originated from the Toyota Production System, was considered as one of the most effective production management models in the current Production and Operations Administration (Barud et al., 2020).

According to Barud et al. (2020) and Rodrigues (2014) the systematization of Lean is made from the integrated focus of the production and consumption cycles, considering the product as the main link between the operation and the customer, as shown in Figure 1.

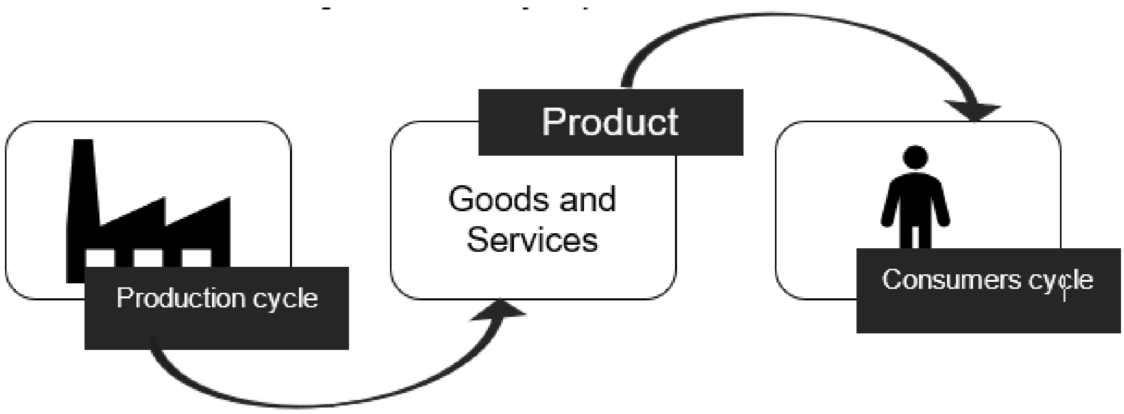

Figure 1 - Cycle of production or consumption. Source: Adapted from Rodrigues (2014).

Lean also has other names such as Lean Production, Lean Enterprise and Lean Thinking. In Brazil, lean thinking has the main objective to maximize value for the customer through a value stream, without waste, aiming at perfection in the operation. Lean Thinking is composed of 5 principles: (i) understand what value to the customer is; (ii) map the value flow; (iii) establish a continuous flow without waste; (iv) boost production and, finally, (v) seek perfection in the operation (Werkema, 2016; Guimarães et al., 2020).

2.2 Lean Six Sigma

The term Lean Six Sigma, arose from the desire to unite the good practices of Lean production with technical tools and methods used in Six Sigma. The Six Sigma methodology is associated with actions that seek improvement for the project process, called Six Sigma Projects (Werkema, 2016).

The constitution of teams for the development of projects is an element of the Six Sigma infrastructure, which contributes immensely to the achievement of the strategic business goals, being an excellent structure for the conduction of projects of improvement of processes and even of quality. (Montgomery and Runger, 2011).

3. Proposed Method

The research is classified as a case study since the study focuses on reducing waste in the hospital product line and increasing the production capacity to meet the demand arising from the COVID-19 pandemic. The nature of the research is qualitative and quantitative, since the processes involved and steps are analyzed quantitatively. The method was the case study, where the investigation of the problem was carried out and actions were taken on the object of study (Yin, 2015).

The action plan below mirrors the sequence of the stages of the DMAIC cycle. Table 1 shows how the steps of the methodological procedures were.

Table 1 - Step-by-step on DMAIC process.

Steps	**Actions**
Define	D1 – Problem Definition; D2 –Target definition.
Measure	M1 – Definition of Stratification Criteria; M2 – Data Gathering for stratification M3 – Stratification analysis; M4 – Focus variation analysis; M5 – Specific goals definition;
Analyze	A1 - Survey of causes; A2 - Prioritization of causes; A3 - Definition of the fundamental causes to be treated in improve.
Improve	I1 – Survey for solutions for any cases; I2 – Prioritizing Solutions (If there is more than one solution for the same cause); I3 – Action Plan 5W2H; I4 – Implementation of Actions and monitoring.
Control	C1 - Verification of the achievement of the project's goal; C2 - Reflection on learning and recommendations.

In principle, each step of the DMAIC will be addressed, detailing the problem in its current state considering the conditions of the new demand. After that, it will be shown, already in the improve part, a survey of the solutions and the respective future status.

The company XYZ is a leading organization in the segment of hospital instruments in Brazil. Its plant has 250 employees and its average turnover is in the order of 30 billion a year. This case study will present a project developed to increase the production capacity of the hospital extension tube manufacturing line.

4.1 Define

At the beginning of March 2020, the company under study had its demand increased by 137%, according to the comparison of the Output with the Production represented in Figure 2 below:

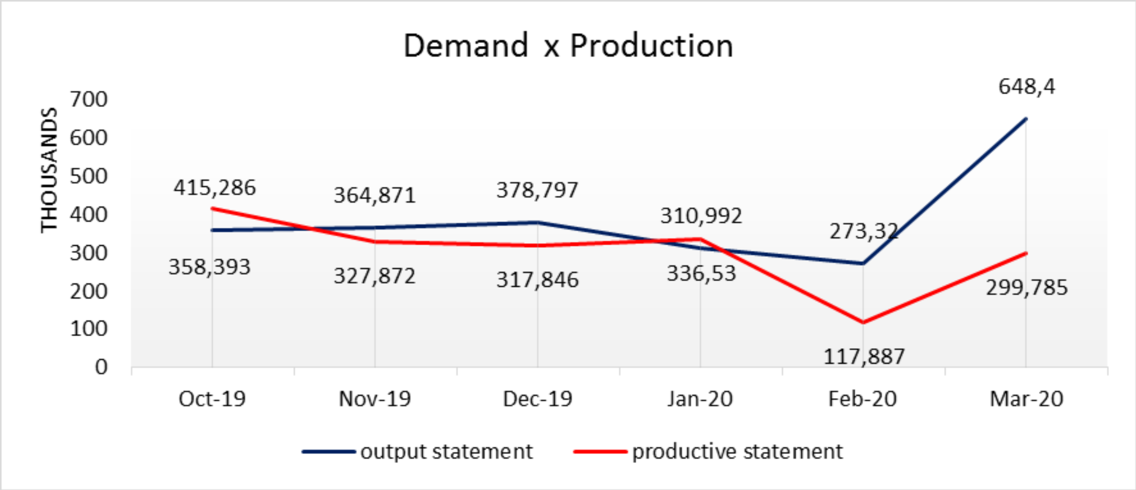

Figure 2 – Demand x Production

Figure 2 reflects the beginning of the Corona virus pandemic in Brazil in March. In this period, the company obtained the most significant demand to date, exceeding the productive capacity of the entire physical installation for the product “extension to the operating room”.

The process of setting up the respirator extension hose is performed by a single operator as it is a simple process, where an employee can perform most of the process. As can be seen in Figure 3 below.

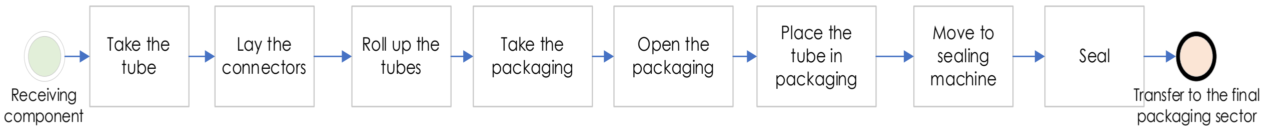

Figure 3 – Main production process for respirator extension hose

It is a process in a fixed position, consisting of 6 resources making the same movement, and 2 resources collecting to seal in a 10-hour day from Monday to Thursday and 9 hours on Fridays, completing the 44 weekly hours worked per employee.

After collecting these data, the achieved x expected productivity was compared, as shown in Table 2 below.

Table 2 - Hospital respirators hose extention production table.

Cód	Description	Realized productivity	Expected productivity	%
9532	Hospital Extension CC 5,6mm - 2,0m	120	150	80%
9543	Hospital Extension CC 5,6mm - 3,0m	86	166	52%
9544	Hospital Extension CC 6,4 mm - 3,0m	57	57	100%
9553	Hospital Extension CC 5,6mm - 6,0m	76	76	100%
9563	Hospital Extension CC 5,6mm - 4,0m	41	41	100%
9565	Hospital Extension OX 4,7mm - 1,5m	167	182	92%
9566	Hospital Extension OX 4,7mm - 2,0m	150	165	91%

It was possible to notice that Hospital Extension CC 5.6mm x 3.0m is the one with the lowest performance, being 52% of the expected productivity. This is intended to increase the performance level by 89% (from 86 to 163), that is, to obtain about 98% of performance in the process in question at Hospital Extension CC 5.6mm x 3.0m until 06/01 / 2020.

4.2 Mesure

To diagnose the process, information from the operation was collected for 36 days. This information can be analyzed in Figure 4, below:

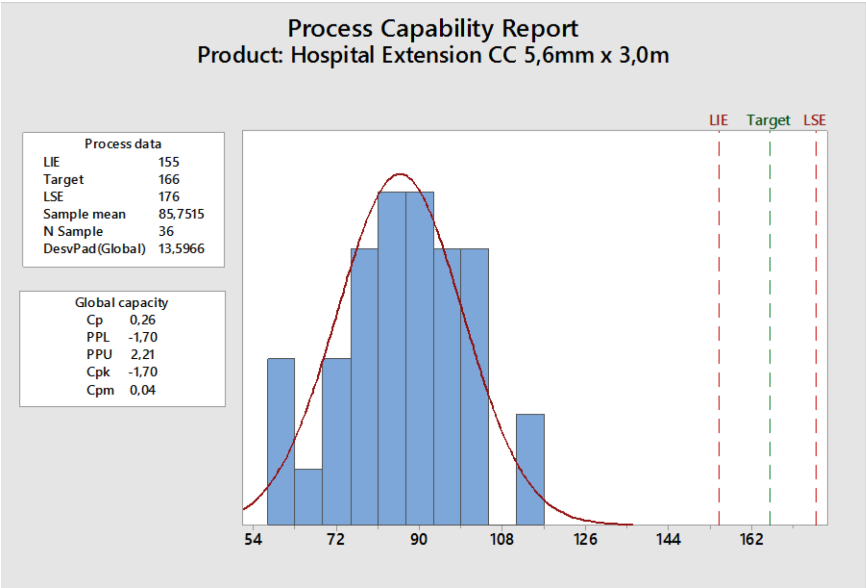

Figure 4 - Process Capability Report of Hospital Extension CC5,6mm x 3,0m

Note that the average production of each operator is 85 extensions per hour. The variability of operators is 13.59 tubes. It can also be noted that the indicators point to an unbalanced process with a Cp equal to 0.26, which represents a high variability of the process. It is understood that the process is incapable, with a Cpk of -1.70, obtaining results outside the control limit, and also has a standard deviation of 13.59.

4.3 Analyze

The low productive capacity can have different sources, so for a better understanding of all the means that can hinder the assembly of the Respirator hose CC 5.6mm x 3.0m, the team elaborated an investigation based on the day to day process enabling the stratification of the problem.

Based on the understanding of the split tree represented in Figure 5, we tried to understand the points that most affect the productivity and it was concluded that rework and the non-conforming configuration of the assembly line were strong candidates.

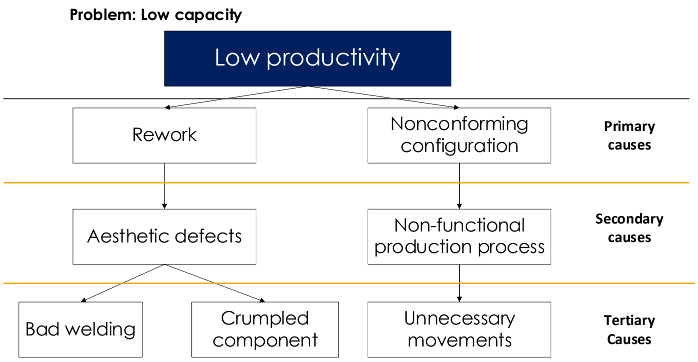

Figure 5 - Problem Stratification Analysis.

There are two focuses in which directly impact the production process of Respirator Hose CC 5.6mm x 3.0m. Due to the current pandemic moment, it was agreed that the nonconforming configuration layout improvement would not be suitable at the moment due to the urge of demands and also high level costs. Therefore, the analysis line was based upon rework indicator as Figure 6 shows below.

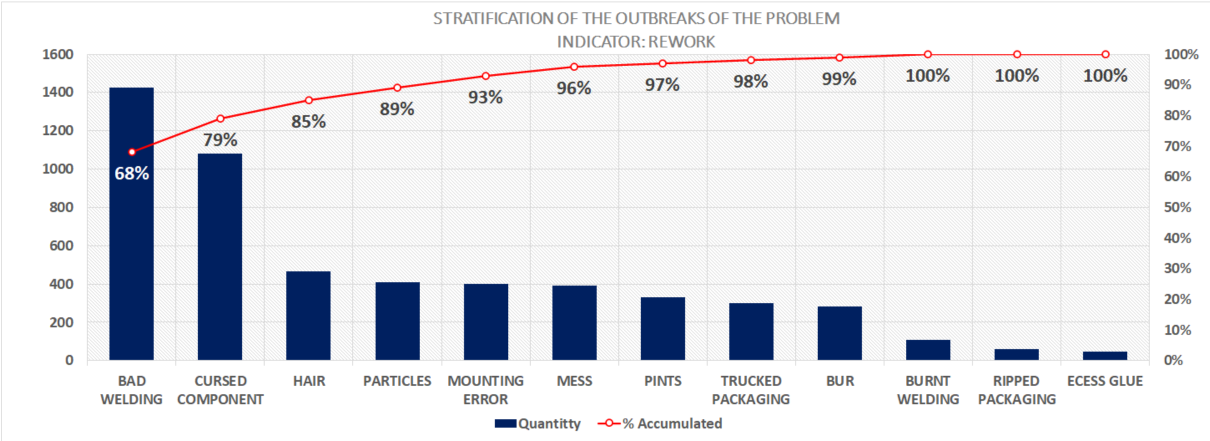

Figure 6 - Paretto Chart on Stratification of Problem regarding "REWORK" indicator.

Bad welding and dented component are responsible for nearly 79% of the nonconformities presented on Rework. At this moment all efforts were directed for those two main causes. A 5 Why investigation were also performed to define what the root cause could be. A local interview were performed and with the outcome revealed in Figure 7.

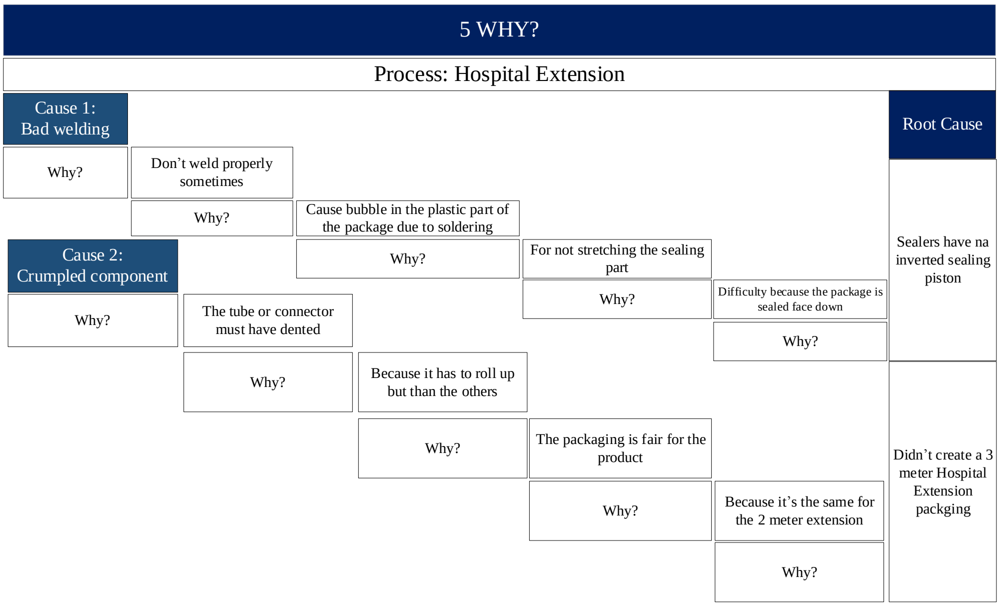

Figure 7 - 5 Whys analysis with production team.

The responses were unanimous from the six interviewed process team. In cause 1, the root cause analysis has found that the sealer does not conform to the process, as it burns the weld and make a defective product. When employees were trying to seal, they see the back of the packaging that is made of paper and seal, preventing seeing any kind of non-conformity in the product and causing bubbles in the weld by welding askew, with air etc.

The process arose the questioning of "why not seal with the plastic facing upwards". The answer was that the piston in the sealer is configured to seal on the paper part, making the heat pass through the paper and then melt the plastic and, finally, seal the packaging. With this, the cycle time of this process reaches 2.5 seconds.

In cause 2, it was arrived at the essence that the packaging used in the assembly in the extension of 3 meters is the same used in the one of 2 meters, measuring 25cm x 25cm because of this, it generates difficulty in the assembly increasing the processing time.

4.4 Improve

After identifying the potential causes, a new brainstorming was carried out to determine the solutions making possible to retain important information regarding the processes involved. Table 3 has the proposed solutions regarding the fundamental causes identified.

Table 3 - Proposed solutions for each fundamental cause.

Causes	Fundamental causes	Proposed Solutions
1	Bad Welding	Invert the position of the piston on the sealer allowing that the product can be faced top.
2	Bent Components	Exchange of the packing that is used on the assembly process of the Respirator Hose CC 5,6mm x 3,0m

The proposed solution was briefly discussed and after this an action plan was established to achieve the proposed objective of production time reduction. The first solution made was to replace the sealer piston, it was removed and measured by the maintenance sector and a service was requested from a service provider, to change the sealer piston, with the authorization of the quality sector, claiming that at the end of the year they would be calibrated again, the first sealer was modified and tested and did not present any apparent problem in the product, after changing one for testing, the others were changed, not only from the Hospital Extension assembly process, but from the entire assembly sector. factory, because it is easier, practical, quick and useful for the process. The sealing time with the piston at the bottom was 2.4 seconds with the change dropped to 1.8 seconds directly impacting the product's processing time.

The second solution, was the primary packaging, allowing the employee to have greater handling in the process of placing the Extension in the packaging, a small change, but which reduced the production cost of the product in question. Medium packaging 25cm x 25cm, the company's Marketing was asked to increase the package to 25cm x 28cm.

4.5 Control

In order to control the activities performed training processes were projected on a regular basis, and also due to a *lean six sigma* approach, all the workers were engaged to help on nonconformities identification. The controls established at this stage were turned to a six month periodical assessment to ensure that the equipment was performing well.

5. Results

Due to the implemented solutions, in the process of assembling Hospital Extension those responsible for the improvement project, again measured the productivity of the process in question and compared it with the previous months. As shown in Figure 8 below.

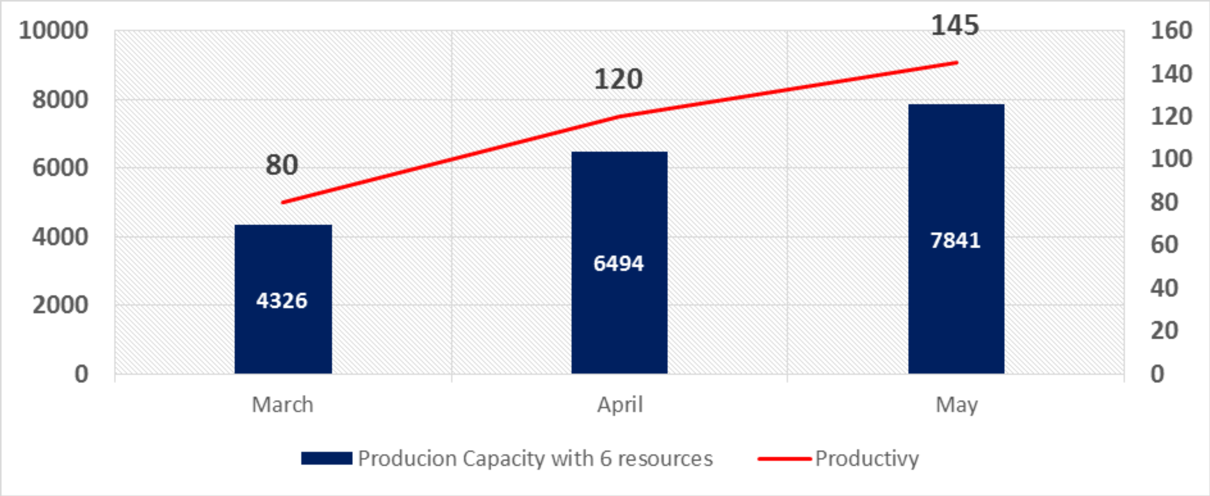

Figure 8 - Production Increase during Lean Six Sigma approach.

Based on the information in the month of May, it can be seen that changing the packaging, reducing the time and increasing the quality of the sealing, made the production capacity increase from 4326 to 7841 (55,12%).

6. Conclusion

This case study went to analyze its processes continuously, aiming to eliminate waste, thus increasing the degree of reliability of its customers and consumers.

An improvement methodology was proposed based on the Lean Six Sigma DMAIC method, which allowed to measure the effectiveness of the process in question, to analyze the opportunities for improvement to promote company production capacity growth by reducing processing time. Due to the pandemics demand variation scenario, the method was essential to understand the process as a whole and also reduced time loss in some processes reducing the costs per piece.

The production of this work was extremely important to expand the improvement models for the industry, more precisely for the assembly sector, becoming a trend and influence for several sectors. A formidable challenge was to adapt the DMAIC methodology in the process, as there is no continuous improvement culture in the industry. Despite the challenges faced, it was possible to achieve 70% of the objective of the project, increasing in 55% production capacity stratifying the nonconformities and making precise actions to increase the productive capacity of Hospital respirators Extensions and consequently attending more hospitals that were taking care of COVID-19 infected people.

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